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WATER QUALITY STUDIES IN THE KENTUCKY COALFIELDS: THE TREND STATION PROGRAM

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The Kentucky Department for Natural Resources (DNR) is revising its approach to their Cumulative Hydrologic Impact Assessments (CHIA), a required decision document gauging the effects of a proposed mining operation on the hydrologic balance of the specified watershed.

One important aspect of this CHIA revision is a change in the scale at which impacts are viewed, from river basins or sub-basins to watershed-scale impacts. To evaluate watershed impacts, it is necessary to review data from past (bond-released), present, and anticipated coal mining permits. Each permit application contains baseline surface and ground water data, during-mining water quality results and continued monitoring through bond release. Unfortunately, most of the past 35 years of data exists only on paper; to conduct trend and modeling analyses, an electronic format is required.

Cumulative hydrologic impacts are the aggregate effects on hydrologic parameter values at a particular location in the hydrologic system, caused by existing and anticipated mining and other activities related to residential development, roads, agricultural, logging and oil and gas well operations. The trend station, located at the mouth of selected HUC-12 watersheds, provides a measure of cumulative effects of these activities as well as multiple mining operations and allow, over time, the ability to predict parameter outcomes for each proposed operation in that watershed. This monitoring network will not only measure the cumulative effects of coal mining in the state but also provide water quality data to water quality agencies and coal industry stakeholders.

Phase I of the trend station program measured water quality in 64 watersheds with 4 quarters of sampling completed during 7/7/11 and 5/12/12. Phase II, consisting of 69 additional watersheds were sampled for three quarters beginning 7/23/12 and ending 2/28/13. Phase III which began in May 2013 will result in all 133 trend stations being sampled three times by December 2013. Funding for Phase III will continue until December 2017. Though over 350 HUC-12 watersheds are located within the Kentucky coalfields, the Phase III stations represent over 95% of mining activity locations in Kentucky.

The parameters measured on-site were air and water temperatures, pH, specific conductivity, and stream flow. Laboratory analyses of acidity, alkalinity, hardness, total

iron, total manganese, sulfates, selenium and several other trace metals that may be associated with mining operations were conducted.

Sulfates may be generated from any earth-moving activity but are generally accepted as evidence of mining operations. No warm water aquatic habitat standard has been promulgated but a sulfate concentration of 250 mg/L is the maximum allowable in-stream concentration for domestic water supply sources. It should be noted that the domestic water supply source standards for TDS are also 250 mg/L even though sulfate is a component of TDS. Buckhorn Creek and Lost Creek in Breathitt County were found to have average sulfate values of 844 mg/L and 665 mg/L, respectively. Lower Balls Fork in Perry County recorded an average concentration of 870 mg/L sulfates. Robinson Creek in Pike County reported an average sulfate level of 608 mg/L. However, various trend station samples in Clay, Harlan, Johnson, Knott and Knox counties recorded sulfate values of 16-67 mg/L. In the western coalfield, Muhlenberg County samples recorded sulfate levels of 900-2270 mg/L. Ohio and Hopkins County reported sulfate values ranging from 600-900 mg/L. The median sulfate concentration for all trend station samples is 162 mg/L.

The highest conductivity level of 3,280 µS was reported from Muhlenberg County. Daviess County reported 2,340 µS. In eastern Kentucky, a trend station in Breathitt County measured 2,010 µS. The median value for all trend stations was 529 µS, a level unexpectedly low given all the contributions of various salts in the entire watersheds. Stations in Clay, Lawrence and Bell counties reported values of less than 100 µS.

Total dissolved solids (TDS) basically mimic or parallel the same trend (and locations) as conductivity. The median value for all trend stations for TDS is 333 mg/L.

During Phase II and Phase III, no exceedences of in-stream standards of selenium (5.0 µg/L or greater) have been recorded. The Phase II station with the highest selenium (3.64 µg/L) is found in Perry County. The Pigeonroost Fork watershed in Martin County recorded 3.60 µg/l selenium. From a total of 862 trend station samples now taken, only 3 exceedences have occurred (Phase I): 7.83 µg/L, 5.13 µg/L and 5.09 µg/L, all in Pike County.

Future investigations include sampling a few watersheds that consistently show high levels of TDS, sulfates or other constituents of concern and to identify the sub-watershed areas that reflect the problem. Since there is wide variation in levels of TDS, sulfates, conductivity and selenium even within a county, the trend station results may assist in identifying coal seam complexes that generate constituents of concern.

WATER QUALITY STUDIES IN THE KENTUCKY COALFIELDS: A CLOSER LOOK AT PIGEONROOST FORK, MARTIN COUNTY, KY

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The Pigeonroost Fork watershed in Martin County, not only contains several active coal mining operations and many (bond) released permits but also unmined areas in the headwaters, a relatively rare occurrence in the eastern Kentucky coalfield. This HUC-12 watershed encompasses 25.03 square miles (16,019.94 acres) and is relatively sparsely populated with 61 residences. Pigeonroost Fork is approximately 7.3 miles long, draining seven main tributaries. One tributary in the headwaters is Hobbs Fork, designated by Division of Water (DOW) as an Outstanding State Resource Water (OSRW). The presence of federally-listed threatened/endangered species has not been identified in this watershed. Extensive mining has occurred in the northwest quadrant of this watershed with active mining operations and bond-released (fully reclaimed) minesites covering 79.1% of the watershed acreage. Coal beds within the watershed include the Richardson, Broas, Peach Orchard, Stockton and Coalburg seams. At this time, no coal removal is occurring and all operations have been idled. Additionally, 186 oil and gas wells are present within the watershed.

From April 2012 to August, 2013, monthly water samples were collected upstream and downstream of tributaries associated with active mining operations to characterize the chemistry of mine discharge water and to determine the cumulative effects in water quality from several operations by sampling at the mouth of the watershed. Similarly, samples from unmined areas were collected to provide a baseline reference to gauge possible mining impacts. The constituents of concern can then be tracked from the mouth of the watershed (trend station) to its possible source.

This project subsequently led to a more detailed study of the effect of a hollowfill, over time, on the quality of the water being discharged from the underdrain of that fill, into the receiving tributary. Discharges from several fills in this watershed, varying in age from 10-30 years were sampled for pH, conductivity, total dissolved solids, total iron, total manganese, sulfates, selenium and other trace metals. To supplement these samples, discharge monitoring report data from the associated sediment ponds of the selected fills were harvested from the DNR database as well as surface water monitoring data from permit files from 1973 to the present. Additionally, geologic data from the nearest core holes to the selected fills were collected to investigate if the potential acidity and/or neutralization potential of the strata and the chemistry of the coal seam correlated with the water quality of the fill discharge. To locate many of these older fills, LiDAR

technology was utilized as an extensive tree canopy and mature vegetation characterized the fully reclaimed mining areas.

Preliminary findings:

Total manganese and total iron concentrations tend to reflect a cumulative effect in the Pigeonroost watershed. Values of these analytes are often lower in the mined tributaries than at the trend station at the mouth of the watershed. However, no in-stream standard has been exceeded.

A benthic macro-invertebrate/fish survey was conducted on a mined tributary and an un-mined (OSRW) tributary with the results shown in the table below:

	Un-mined (OSRW) trib.	Mined trib.
Taxa richness	33	31
EPT Taxa Richness	19	16
mHBI	2.7	3.0
% EPT	90.9	79
% Ephemeroptera	63.1	28.8
Total No. Individuals	252	219
MBI Score	85 excellent	72.6 good
Fish Taxa	7	14
KIBI Score	25 poor	45 fair
Habitat Assessment	157 fair	147 fair

Results from sampling at the toe of 8 hollowfills showed wide variation in the concentrations of the chemical constituents with selected parameters in the table below. It should be noted that the newer fills discharged less selenium than the older fills. Older fills discharged less total iron and total manganese than the newer fills.

Age of fill	Conductivity µS	TDS mg/L	Sulfates mg/L	Selenium µg/L
10 yrs (1 fill)	801-925	504-578	210-264	0.6-0.89
12-24 yrs.(6 fills)	1,680-3,340	716-2,780	404-1,750	1.04-15.2
33 yrs. (1 fill)	2,770-2,950	2,100-2,310	1,170-1,320	4.2-4.3

Still under investigation: The historical data from discharge monitoring reports and surface water monitoring points will be compared to the sampling points in the current study to better understand the trend of water quality from the hollowfill, through the sediment pond, to the tributary, to the main stem and to the mouth of the watershed. Statistical analyses will include how analytes are correlated (or not) and which analytes may predict or characterize the water quality health of the watershed.

WATER QUALITY MONITORING OF THE MCCONNELL SPRINGS STORMWATER QUALITY WETLAND POND AND GAINESWAY POND RETROFIT PROJECT, 2010-2013

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In December 2009 the Lexington-Fayette Urban County Government (LFUCG) completed construction of the McConnell Springs Stormwater Quality Wetland Pond, consisting of a pre-treatment gross debris trap, three settling forebays, a 0.2 acre deep-pool pond, and a 0.5 acre shallow marsh/littoral shelf area. The purposes of this facility were to reduce non-point source pollution entering McConnell Springs and neighboring impaired streams Wolf Run, Town Branch, and South Elkhorn Creek; and as a public demonstration of the benefits that natural environments provide to water quality and quantity control. Four floating wetland island designs were tested in the McConnell Springs Wetland Pond in June, 2013 by Friends of Wolf Run volunteers in cooperation with both LFUCG Division of Parks and Recreation and Division of Water Quality, McConnell Springs Nature Center staff, and several community groups. The floating wetland islands provide an additional treatment system in stormwater retention ponds. Construction of the islands was funded by the Kentucky American Water Environmental Grant Program. In Spring 2009, LFUCG remediated Gainesway Pond at Centre Parkway as part of the Gainesway Retention Basin Water Quality and Environmental Education Project. The goal of this project was to retrofit the existing Gainesway Pond to increase pollutant removal through addition of constructed wetlands, aquatic plantings, aeration, and upstream biofiltration/gross debris traps. The Gainesway project also provides the community with environmental educational opportunities. Both of these projects were funded in part through a §319(h) grant provided by the U.S. Environmental Protection Agency and administered by the Kentucky Division of Water.

To determine the on-going effectiveness of pollutant reduction by the two stormwater projects, LFUCG Division of Water Quality collected water samples in 2010-2013, with emphasis on runoff samples during storm events. Five sampling sites were identified at McConnell Springs, sites M1-M3 were located in the pre-treatment and forebay cells and sites M4-M5 were located in the main pond. Five sampling sites were also identified for Gainesway Pond: upstream, mid-stream, wetland area, Pond A, and Pond B (i.e., GP1-GP5). A total of 23 sampling events were conducted at McConnell Springs and 18 sampling events at Gainesway Pond in 2010-2013. On-site measurements included: temperature, pH, ORP, dissolved oxygen (DO), conductivity, and total dissolved solids (TDS). Additional analysis included: alkalinity, hardness, carbonaceous biological oxygen demand (CBOD5), total suspended solids (TSS), total ammonia, nitrate, nitrite, total phosphorus, orthophosphates, and bacterial enumeration (fecal coliforms, *E. coli*, and total coliforms). Metals in water samples from McConnell Springs were analyzed in 2010 and 2013 and from Gainesway Pond in 2013.

Overall pH values at the McConnell Springs stormwater structure remained constant from 2010 to 2013. In general, DO concentrations increased through the system, with sites M4-M5 having the highest DO. Total alkalinity remained constant with values ranging from 55 to 78 mg/L for 2010-2013. Hardness was elevated in 2010 (343 mg/L), but average concentrations decreased in 2011-2013 as the system became established. The range for TSS was 14-24 mg/L from 2010 to 2013 with lowest values at sites M4 and M5, except for an increase on 8/22/13. Overall ammonia levels for 2010-2013 decreased at sites M4-M5. Similar reductions were found for nitrate and nitrite. Concentrations of total phosphorous and orthophosphate decreased through the system. Average total phosphorous and orthophosphate concentrations were lower in 2013. Overall reduction in bacterial counts were observed from 2010 to 2013. Fecal coliform geometric means for 2010 to 2013 were 34330, 860, 350, and 570 MPN/100 mL, respectively. Whereas, geometric means for *E. coli* were 1014, 755, 590, and 487 MPN/100 mL. Of the 30 metals tested in 2010, the concentrations of Al, Cu, Fe, Ni, S and Zn decreased through the stormwater facility. With the exception of sulfur, all detectable metal concentrations were lower in 2013. Metals not detected in 2013 included Ag, Cd, Ni, and Zn. All four floating wetland islands flourished during their trial period (6/25/13-10/31/13). The islands provided habitat to a variety of wildlife and were well received by the public. The limited contact time was not sufficient to determine any effects on pollutant removal, however, there is interest to continue this trial for a full growing season in 2014.

At the Gainesway Pond stormwater structure the overall pH levels remained fairly constant. DO levels ranged from 5.74 to 7.84 mg/L, with the lowest DO levels observed at the wetland site (GP3), but increasing in the downstream ponds (GP4-5) in part due to the aeration fountain. Total alkalinity and hardness concentrations were fairly constant in 2010-2013. Average alkalinity values ranged from 150 to 207 mg/L and average hardness values ranged from 150 to 265 mg/L. Average yearly TSS concentrations have been increasing since 2010, with values of 8, 10, 13, and 20 mg/L for 2010-2013, respectively. Higher TSS values in the wetland area were expected. Average ammonia concentrations increased slightly over time. However, decreasing levels of nitrate and nitrite were observed from 2010 through 2013. Total phosphorous has remained somewhat constant over time whereas orthophosphate concentrations have decreased. In general, bacterial counts were generally highest at upstream sites and decreasing in the ponds. A reduction in fecal coliform counts was observed in 2013 as compared to 2010. However, *E. coli* counts increased in 2013, with geometric means of 763, 589, 500, and 1000 MPN/100 mL for 2010, 2011, 2012, and 2013, respectively. Metals not detected in 2013 included Ag, Cd, and Zn. Concentrations for Fe, Mg, Mn, Ni, K, and S were highest at GP3.

Based on four year monitoring data, the structures are performing as expected. More consistent results are being obtained as the systems become established. Reductions of several pollutants were observed at both systems. Of interest were the reductions in bacterial counts over time at McConnell Springs, and reduction of metals at both projects. These reductions aid in decreasing urban stormwater impacts on neighboring streams. Although no significant reductions could be attributed to the floating wetland islands, further studies will be conducted in 2014. LFUCG will continue to monitor water quality regularly with close monitoring of ammonia, total phosphorous and bacterial counts which can have detrimental impacts to the facilities and receiving waters.

WATER QUALITY MONITORING OF MCCONNELL SPRINGS, LEXINGTON, KY

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Since the completion of the McConnell Springs Stormwater Quality Wetland Pond by the Lexington-Fayette Urban County Government (LFUCG) in 2009, the system has been monitored by the LFUCG Division of Water Quality to determine the effectiveness of pollutant reduction. While on site, additional water quality monitoring was performed on McConnell Springs itself. McConnell Springs is located in northwest Lexington, KY. The spring system consists of the Blue Hole, where water emerges from an underground channel and flows for approximately 38 m (125 ft.) then disappears underground; the Boils, at this point water emerges again as an artesian spring and flows for approximately 152 m (500 ft.); the Final Sink, the point where water disappears underground again. The water reappears at Preston's Cave and flows into Wolf Run Creek, which empties into the Town Branch of Elkhorn Creek. Water quality monitoring included the Blue Hole, water at a small cave opening, the Boils, and the Final Sink. A total of 15 sampling events were conducted by the LFUCG Division of Water Quality at McConnell Springs in 2011-2013. On-site measurements included: temperature, pH, ORP, dissolved oxygen (DO), conductivity, and total dissolved solids (TDS). Additional analysis included: alkalinity, hardness, carbonaceous biological oxygen demand (CBOD5), total suspended solids (TSS), total ammonia, nitrate, nitrite, total phosphorus, orthophosphates, and bacterial enumeration (fecal coliforms, *E. coli*, and total coliforms). Metals in water samples from McConnell Springs were analyzed in 2013 and included: Ag, Al, As, Cd, Cr, Cu, Fe, Pb, Mg, Mn, Ni, P, K, S, and Zn.

Overall pH values at McConnell Springs remained consistent from 2011 to 2013. DO concentrations remained low, with the Blue Hole having the lowest DO and the Final Sink with the highest DO. Average DO concentrations were 4.49, 4.62, and 3.90 mg/L for 2011-2013. Conductivity was fairly constant, although higher levels were observed in 2013. TDS, total alkalinity, and total hardness remained constant during the monitoring period. TSS levels were fairly low throughout McConnell Springs. Although TSS concentrations were higher in 2012, the levels were not significantly different than the other two years. Overall ammonia levels for 2011-2013 were similar. Nitrate concentrations were highest in 2011 (6.45 mg/L), but decreased in 2013 (2.51 mg/L). Decreasing nitrite concentrations were also observed in 2013. Both total phosphorous and orthophosphate concentrations were fairly constant throughout McConnell Springs and over time. Of the 15 metals tested in 2013, Ag, Cd, Cu, Pb, and Zn were not detected at any of the sites on McConnell Springs. Low levels of Ni were detected at all sites, with the Blue Hole having the highest concentration (0.0023 mg/L). Additional metal testing will be conducted in 2014.

Fecal coliforms and *E. coli* were detected in McConnell Springs during the monitoring period. In 2011, Dr. Gail Brion (UK-ERTL) reported contamination by fecal material in McConnell Springs. Dr. Brion proposed that the cold underground flow may retard fecal aging and that the cold, dark conditions repressed indigenous bacterial growth while enhancing introduced coliforms, thus indicating that the source is not local and may be some distance from the collection site. Fecal coliform geometric means for 2011 to 2013 were 492, 406, and 1035 MPN/100 mL, respectively. Whereas, geometric means for *E. coli* were 317, 375, and 756 MPN/100 mL. All bacterial enumerations tended to be elevated in June and October for all three years. Similar trends were observed in Dr. Brion's 2010 data.

Most of the water quality results observed were consistent with levels found in artesian springs. Of interest were the elevated levels of nitrates and these will be followed closely. Fecal contamination has been a historic problem at McConnell Springs. Additional source tracking is required to reduce bacterial counts. LFUCG will continue to monitor water quality regularly. In particular, close monitoring of ammonia, nitrates, total phosphorous and bacterial counts which can have detrimental impacts to McConnell Springs and the receiving waters of Wolf Run Creek and Elkhorn Creek will be continued.